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PROPOSALS FOR A NEW LIGHTING CODE

By H. C. WESTON *(Fellow)*

(Paper read on Tuesday, January 12th, 1943.)

1. Introduction.

The decision to prepare an I.E.S. "code" of illumination values was taken by the Council of the Society in 1932. In December of the following year, A. W. Beuttell, then chairman of the Technical Committee, presented a paper (1) describing a method of computing values of illumination for good seeing of different visual presentations. It required a knowledge of the way in which facility of vision, or the accomplishment of visual tasks, varies with their characteristics and with illumination. Given this, it should be possible to specify the optimum illumination for any specific task after measuring, for example, the size of detail and contrast it presents. The method is a scientific one, "as exact as it *can* be with the instruments available, or as it *need* be for the uses to which it is put."*

As an outcome of this paper, investigation was initiated by the Illumination Research Committee of the Department of Scientific and Industrial Research with the object of ascertaining some of the relationships upon which the application of the method depends. In 1935 the results of the first investigation, dealing with the relation between illumination and size of work (2), were published. Studies of the effect of brightness contrast were subsequently undertaken and, though completed before the present war, the results have not yet been published. The proposals put forward in the present paper are largely based on the results of these investigations.

In the meantime, recommended values of illumination were prepared mainly on the basis of what experience suggested was "good practice," and were first published by the Society in 1936. Several revised versions have been issued, the most recent being that of January, 1942.

The "code" has come into considerable prominence during the war. It has been cited by the Departmental Committee on Lighting in Factories as a guide to sufficient lighting for specific processes; its recommendations have been accepted by the Production Ministries and applied to the lighting of vital factories; it has been put in evidence in the Courts. Being based on "good practice" means that its recommendations are true in the pragmatic sense—they seem to work well. So do the recommendations of other codes which are different. But it is not known *how* well they work, nor whether they work uniformly well, whether this and that illumination is equally well chosen for this and that purpose. Most existing codes have undergone periodic revision in which values of illumination have been stepped up. This is partly the outcome of new knowledge and experience, and partly due to the cheapening of lighting so that, from time to time, higher illuminations have become economically feasible or acceptable to the user.

The more general acceptance of a lighting code, and especially its adoption as the basis of legal requirements, may, however, be expected to depend on its formulation on a more fundamental basis. Given this, the code recommendations should be more stable,—a more precise statement of the results to be expected from their application should be possible, and the illumination for specific visual tasks could be computed. Although all the factors involved in Beuttell's proposals have not yet been studied, it is believed that the available results of research are sufficient for immediate application. They permit the development of a "code" of recommended illuminations, so related to the magnitude of significant task variables as to permit a common and high order of efficiency in seeing most of the visual tasks done in lighted interiors.

The proposals in this paper deal

* Hogben, L., "Mathematics for the Million," page 635.

only with values of illumination. Other factors involved in good lighting, which must be dealt with in a complete lighting code, must be the subject of a separate paper. They are very important. But to regard them as *more* important than the amount of illumination seems unwarrantable. Lighting cannot be made good by avoidance of glare, by even distribution, colour, quality, and so on, if the illumination provided is inadequate; any more than it can be made good by ample illumination without other suitable conditions. But with any code of recommended values of illumination, or method of computing illumination values, it must be implicit that the effectiveness of the values depends upon right lighting in all other respects.

No code can be devised which will relieve the lighting engineer of the onus of applying his intelligence, skill, technical knowledge, and judgment to the solution of every lighting problem on its merits. But, in respect of illumination values, the object of existing codes is to eliminate individual judgment except in classifying the task for which a value is sought, and to give guidance in making this classification. To the extent to which classification of tasks can be done by actual measurement of the variables involved, and the satisfactory illumination can be expressed as a function of these variables, a code, or method of prescription, can be formulated which is more scientific, more authoritative, and more permanent than those now available. Even so, difficulties in application must be expected. They are difficulties of analysis—of deciding where the yardstick is to be applied to the task—and only experience will resolve them. Unless they are general, they do not make a code based on task measurement impracticable, or unsuitable for immediate adoption.

2. "Satisfactory" Illumination.

Every visual task can be done at different levels of illumination, though not with equal facility and efficiency. In considering the legal regulation of lighting, the usual endeavour has been to find values of illumination which are adequate for a "reasonable" degree of safety and welfare. Codes intended to be enforced by law generally specify values which are minima for this purpose. But in the most recent of these—the Australian code, which closely follows our own—ranges of illumination are specified for scheduled processes and classes of task, of which the lower value in each case has been made the legal minimum. The latest American code gives "minimum operating" values, based on "current good practice," which are clearly thought to permit a fairly high degree of efficiency in the performance of the tasks they cover, "though in almost every instance higher values may be used with greater benefit."

The current I.E.S. code gives recommended "service values of average illumination" within the area over which the task is done. These are based on "good modern practice," from which an unspecified, but obviously fairly high, degree of visual efficiency and comfort is expected. In his paper [1] Beuttell took this loosely defined standard of performance or capacity,—neither a minimum nor a maximum but high,—as the index of "satisfactory" illumination, which he suggested might be taken as 1 ft.c. for the "simplest imaginable," or basic, task. Any change in the task, rendering it more difficult, should be countered by a change in illumination such that, if possible, the standard of performance, or facility of vision, is kept unchanged.

For the term "high" a numerical value will now be substituted, defining a standard of efficiency, or relative performance, which "satisfactory" or "recommended" illuminations shall permit. The standard proposed is an efficiency of 90 per cent. This means that for every visual task the corresponding recommended illumination shall be such that a common level of performance, relative to the respective possible maxima, can be reached. In terms of facility of seeing, it means that every task illuminated to the recommended level may be seen nine-tenths as easily as it could possibly be seen, however much better it might be illuminated. It is only in this relative sense that visual tasks which differ much, in the characteristics

affecting their visibility, can be made equally easy by the suitable choice of illumination.

It must be made clear that this standard of relative performance refers only to visual performance, and not to the overall performance attainable with tasks which are partly non-visual. With such tasks—of which there is a majority—when conditions are favourable for a maximum non-visual performance, the overall performance may obviously exceed 90 per cent. of the possible maximum, even if the visual performance is limited to this degree. Thus, when the rate of doing a practical task is only determined by visual efficiency during half the time required to complete it and, during the other half, the maximum rate is achieved, the overall efficiency with recommended illumination will be

$$\frac{100 + 90}{2} = 95 \text{ per cent.}$$

3. Considerations Governing the Selection of a Performance Standard.

The choice of a visual performance of 90 per cent. as the standard on which recommended illuminations should be based must be explained. When visual tasks differ only in size, the contrast they present being constant and nearly ideal, the visual acuity required to see them is, within certain limits, proportional to the logarithm of the illumination (3), and is measured in terms of size. For a size range covering the majority of practical tasks the illumination range does not extend above about 10 ft.c. But the performance considered in measuring visual acuity is a minimum. For maximum performance of similar tasks it has been shown elsewhere (2), that illumination varies inversely, though not simply, with size, and is many times greater than the illumination which just gives the necessary acuity. Maximum visual performance of many industrial tasks would thus require very high illuminations, even if the size of their detail were the only factor concerned. But since the reflection factors and contrast they present must also be taken into account, the requirement of maximum visual performance would involve quite impracticably high values of illumination in interiors. It was also shown in (2) that about 98 per cent. of the respective performance maxima of tasks differing in size might be obtained with illuminations only about one-tenth of those at which the performance maxima occur. But even these illuminations lead to impracticable values when multiplied to give suitable brightnesses for tasks involving low reflection factors and contrast.

If, however, a relative performance of 90 per cent. is chosen, the necessary values of illumination are quite manageable and, for tasks having the most favourable reflection factors and contrast, but differing in size within limits embracing most tasks done with the naked eye, they do not range far above 100 ft.c. It is also found, as will be shown later, that a simple and convenient relation exists between illumination and size for this relative performance level.

Individuals differ in their ability to perform any given task. If the task is wholly or partly a visual one, individual differences of performance may be wholly or partly due to differences of visual capacity, and visual capacity varies with illumination. But the *relative* difference between individual performances may vary with illumination or be independent of it. If the effect of varying illumination is to produce the same *proportional* change in the capacity of A and B for performing a given task, the performance of both will increase with illumination until their respective maxima are reached. But if A is worth two of B at *any* illumination this will be so at *all* illuminations.

Up to a point, however, increase of illumination usually has a disproportionate effect upon the different capacities of A and B, so that the inferior of the two improves to the greater extent. Thus, though A and B may never become equally capable at any illumination level, their capacities will converge towards a common value as illumination is increased. If the improvement of the inferior individual continues to be proportionately the greater up to the illumination at which his performance becomes a maximum, only when this illumination is reached will the relative difference between A and B be a minimum.

But the relative difference between their performances may become independent of illumination before either reaches its maximum, if the growth of each, though disproportionate at low illuminations, eventually becomes proportional. There is some evidence that this tends to occur when the illumination is sufficient for the average of individual performances to be about 90 per cent. of the mean of their maxima. As illumination falls below this value individual differences of performance progressively increase; A and B become more and more unequal. Thus, illumination of this order is satisfactory for the purpose of minimising individual handicaps; of giving all individuals the most nearly equal visual equipment they can have for the task.

4. Specification of the Code Objective.

Some tolerance must be allowed in specifying the standard of relative visual efficiency, or performance, for which recommended illuminations shall be adequate. In the first place, when all the characteristics of the task are unfavourable, e.g., small size, low reflection factors and poor contrast, some departure from the suggested 90 per cent. performance level must be accepted to allow the use of reasonably practicable illuminations. Secondly, it is possible that the relation between illumination and relative performance may vary with the perceptual pattern (*Gestalt*) presented by the task as a whole, and within which the material detail is contained. The relations on which the proposals in this paper are based refer to simple perceptual patterns. It is fairly certain that the absolute values of performance obtainable at all levels of illumination will be lower when similar detail has to be seen in complex patterns. Both the apparent size and the apparent contrast of a given material detail can be modified by the pattern in which it occurs. But, if the pattern has any substantial effect on the illumination—*relative* performance relation, this would seem to be a fundamental objection to the analytical method, since illumination could not be expressed as a function of isolated variables, but only of the pattern treated as a "unitary whole." Thus an ad hoc investigation would be necessary to determine the optimum illumination in each case.

This kind of objection is often raised to the application of conclusions drawn from investigation of one special case to another which, though analytically similar, i.e., containing similar material detail, may be markedly different viewed as an organised whole. The author believes this objection to have little weight against the generalisation of conclusions referring only to relative performance. On this point, however, some uncertainty will be admitted and allowed for in stating the standard performance. It may be added that the ad hoc method, by which each of the vast number of visual tasks occurring, say in industry, would in turn be the subject of illumination — performance tests, offers little hope of substantial progress towards a comprehensive illumination code in any reasonable period of time. Nor is it likely that any resultant gain in the precision with which satisfactory illuminations could be prescribed would justify the immense labour involved.

Thirdly, movement,—for which Beuttell proposed to apply a multiplying factor,—has not been specifically studied, and cannot be dealt with, in the present proposals, on this basis. Movement is always relative, and the most usual case is that in which the eyes move in scanning stationary objects, or the objects are moved before the eyes, the rate of relative movement being under the control of the viewer. The ascertained relations [2] between illumination and speed and accuracy of visual performance take such relative movement into account. But there are other cases where the rate of movement of objects is not under the viewer's control, and pursuit movements of the eyes, or eyes and head, have to be made to keep the object in view. A particular and difficult case of this type is that involving oscillatory movement. In a number of practical cases, however, the movement is slow, and can probably safely be neglected in computing the illumination required. In others, either an arbitrary allowance can be made or, in critical cases, the best illumination

must be found by experiment. In general, it will be assumed that movement may involve some, though not serious, deviation from the standard relative performance.

With the foregoing considerations in mind, the objective of recommended illuminations can be stated as follows: recommended illuminations should be adequate to permit a performance of visual tasks which is *of the order of 90 per cent.* of the maximum possible at any higher illumination. This is subject to a minimum recommended value, applicable however crude or easy the visual task may be. Otherwise, code illuminations are those necessary on the work itself, though their effectiveness is conditional upon general illumination to secure a suitable ratio of environmental to work brightness. It is obvious that low recommended illuminations may well be exceeded in practice, with economy, to permit a performance better than the code standard.

5. The Minimum Recommended Illumination.

The effects of light on physiological functions of the visual sense apparatus are not the only considerations on which to base the minimum illumination of a good-lighting code. The psychological effects of visual stimulation must also be taken into account, so far as they are due to the general level of environmental brightness, rather than to other aspects of the visual environment with which the *art* of lighting must be concerned. Often, the characteristics of the visual tasks to be performed demand such low degrees of capacity that efficient vision is possible with very low illuminations. But this does not mean that such illuminations are desirable, nor that they will always be effective for a satisfactory performance of tasks which only involve crude visual perceptions.

It is a matter of common experience that "feelings" and "moods" vary with sense impressions of all kinds, including those excited by external brightness stimuli. Evidence of this is readily found in expressions which betray the common tendency to objectify feelings—to project them into the external objects which excite them. Typical examples are "a cheerful room" and "a gloomy room." It is, of course, the mental state which is "cheerful" or "gloomy,' the rooms having neither of these qualities of feeling, though differing in the intensity of the general brightness stimulus afforded. Equally evident, in everyday experience, is the fact that moods and feelings affect the whole behaviour of their subjects. Feelings of depression, or gloom, are unfavourable for efficiency at work or play; feelings of well-being and cheerfulness are favourable.*

If an order of brightness, or the equivalent illumination, can be found which is the lowest that will usually be consistent with a satisfactory mood or favourable totality of feelings, this illumination should be the minimum recommended, even though some lower illumination might give adequate visual capacity. A lower illumination than 2 ft.c. may be adequate for seeing detail which subtends a visual angle not smaller than about six minutes; and it has been shown, in (2), that, above this size, *visual* performance can be practically independent of illumination, providing the reflection factors involved in the detail have a difference approaching unity. Nevertheless, *overall* performance of tasks involving only crude visual perceptions, and dependent overwhelmingly on the rate of motor activity, continues to improve up to much higher illuminations.

This has been shown most clearly in the tile-pressing investigations made by Adams (3). The results are plotted in Fig. 1, the output recorded with the highest illumination used—about 14 ft.c.—being taken as 100 per cent. The trend of the curve, however, suggests that some further rise in output might occur with still

* "We never actually find a mind which apprehends things without joy or sorrow, and contemplates them with absolute indifference. In cognising objects we feel ourselves attracted to or repelled from them, or incited to the performance of some kind of action. . . . Feeling and conation always accompany our sensations and ideas; they determine our actions. . . . Feeling and will are closely interconnected. . . ."—Wundt, W., "Human and Animal Psychology."

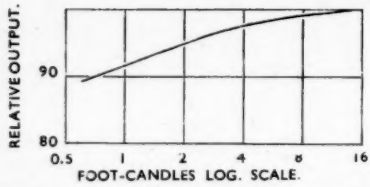

Fig. 1. The relation between relative output and illumination for typical practical case of rough work (tile-pressing).

higher illumination, though only to a slight extent. From the graph it is seen that a relative output of about 95 per cent. is obtained at 2 ft.c., but at least 3 to 4 ft.c. is considered justifiable for economic production. The results are attributed mainly to the general brightness produced. Fig. 2 is plotted from the results of laboratory tests, in which a group of eighteen experienced subjects performed a simple cancellation test. Visual discrimination was easy, even at the lowest illumination, and speed of action was the major factor determining performance. Here a relative speed of about 90 per cent. is shown at 1 ft.c., but 95 per cent. requires about 20 ft.c., and performance is seen to improve up to 500 ft.c.

From these results, it seems clear that when illumination is of the order of 3 ft.c. general activity shows a sufficiently marked depression to make any substantially lower illumination ordinarily unjustifiable. This value is the mean of the lowest range in the existing I.E.S. code. The minimum of this range—2 ft.c.—can be accepted as the lowest value to be recommended, providing it is only used when the nature of the environment illuminated can most efficiently convert it to brightness, i.e., when all the surfaces forming the visual environment are good diffuse reflectors. It is obvious that a single low value of illumination cannot be found which will impart a cheerful brightness to all environments and, while 2 ft.c. may suffice under the most favourable conditions, in others it will need to be increased in inverse proportion to the average reflection factor of the surfaces illuminated.

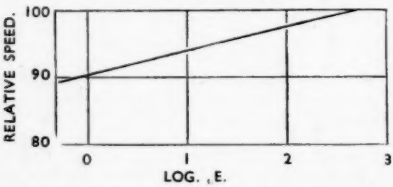

Fig. 2. The relation between log.$_{10}$E and relative working speed for a simple cancellation test involving only crude visual perceptions.

The American code recommends no illumination lower than 5 ft.c. But it is possible that certain special cases may be cited even against the more moderate contention that 2 ft.c. is the lowest illumination that can generally be recommended on psychological grounds. For example, in the manufacture of light-sensitive photographic materials very low illumination is essential, and persons exposed daily to this low environmental, or "ambient," brightness are not known to be habitually gloomy and depressed. Again, during the war, illumination is restricted to a very low value in certain work-places which cannot be fully enclosed, and acceptance of this condition seems to have occurred without general depression. The case of coalmines is a further example.

Common to these cases, however, is a factor which modifies the total feeling, so that it is much less disagreeable than it would normally be. This factor is the idea of justification or inherent necessity. There is a clear apprehension of an adequate reason for a low brightness level in the photographic materials case, and this also applies to the others, even if it is conceded that, in them, the reason is not quite so cogent.

6. Need for a Logarithmic Scale of Illuminations.

When visual tasks are classified according to their difficulty, the classification necessarily involves the comparison of one task with another. It can be judged that *this* task is equal to, more difficult, or much more difficult than *that*, but not that it is one and a half, or n, times as difficult. By successive comparison it can be decided that task B is next to A in order of difficulty, C next to B, and so on. By grading tasks in this way they are arranged in a series, between successive members of which there is

an equally noticeable difference of difficulty.

In principle, this is the basis of the existing I.E.S. classification, a general description or example of each noticeably different grade of task being provided as comparison standards, to be visualised when assessing any given task. Now, if a different illumination is necessary for each grade of task, it is obvious that the difference of illumination in each case must be at least a noticeable one. If tasks are graded by equally noticeable differences of difficulty, the corresponding illuminations, or brightnesses, must also have equally noticeable differences. But, the increments of physical brightness necessary to produce equally *noticeable* differences are equal *proportional* increments, i.e., they bear a constant *ratio* to the brightnesses to which they are added. This is in accordance with the Weber-Fechner law, which is approximately true within the limits of brightness involved in good interior lighting. The series of illuminations corresponding with the series of task categories will thus be a geometrical one,* successive values being in a common ratio, so that A is to B as B is to C, and so on. Another way of putting this is to say that the logarithms of successive illuminations in an appropriate code series differ by an equal amount. If, therefore, members of the series of noticeably different task categories are numbered, from the easiest, in arithmetic progression, 1, 2, 3, . . . n, these numbers are the logarithms of the corresponding illuminations, when the base E of the illumination series E^n is suitably chosen.

In the present I.E.S. code, this law of the logarithmic relation between illumination (or, strictly, brightness) and difficulty of the visual task can be seen to underly the recommendations. But it is not consistently applied. Obviously account is taken of the fact that, as the illumination scale is ascended, the arithmetic difference between successive values must be increased in magnitude if it is to be an effective step. But a constant proportionality is not observed; the ratio of successive values in the series varies between 1.5 and 2. This suggests that the corresponding classes of task differ in difficulty by unequal amounts; that it has been possible to assess the relative difficulty of the tasks in different categories so nicely as to say that B is x% more difficult than A, while C is y% more difficult than B. In fact, this would be a difficult and very dubious procedure, and was probably never contemplated in preparing the code. The want of strict proportionality between successive code illuminations appears rather to be due to considerations of practical convenience, as in the choice of light sources to be used to provide illuminations within the respective ranges. Considerations of this kind are not germane to a scientific code. Moreover, it will be shown to be quite unnecessary to introduce any irregularity into the series of recommended values as a practical expedient, since the permissible tolerance for all values will be fully adequate to satisfy convenience in planning installations. The presence of irregularity must always obscure any underlying rule of the code, and appear puzzling, or arbitrary, to critical light users, whose acceptance of the code is desired.

Irrespective of other proposals made in this paper, it is, therefore, suggested that recommended values of illumination should, in future, form a true geometrical series, except for deviations necessary to avoid fractions. This rule is followed in the latest American recommendations. Those of the recently published Australian code differ from our own only in dividing the range 2 to 10 ft.c. between two in-

* "Long before quantitative methods in psychology were thought of, astronomers had occasion to classify the stars according to their relative brightness. The different classes are arranged in a scale. At the top of the scale comes the brightest; the unlikeness in average brightness between this and the second class is equal to the unlikeness in average brightness between the second and third class, and so on. The corresponding intensities of the physical lights have since been determined; and it is found that they approximately form the geometrical series $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, 1-16, etc. Here each stimulus is the half of the preceding stimulus."—Stout, G. F., "Manual of Psychology."

stead of three classes of task, but are similarly irregular in their proportionality.

7. Range of Recommended Values.

It has already been suggested that the lower limit of the range of recommended values of illumination can remain at its present value of 2 ft.c., since, where the surroundings are most favourable, reasonably satisfactory psychological results are possible, and crude visual tasks can be performed with an efficiency of about 90 per cent. The minimum of 6 ft.c. specified in the prevailing Factory Lighting Regulations makes suitable allowance for the relatively unfavourable nature of the surroundings in the average factory.

The existing I.E.S. code leaves the upper limit of illumination indefinite, giving it merely as upwards of 50 ft.c. But, to make possible a relative speed and accuracy of vision of the order of 90 per cent., about 1,500 ft.c. appears to be necessary for some industrial tasks. It may be said at once, however, that illuminations approaching this value are only needed on the work itself and should be confined to it. And as the work may occupy only a small area, no great difficulty or expense may be involved in illuminating it to a very high level. Where specular material is concerned, the corresponding brightness—which, of course, is the actual visual stimulus—is often easily got, and sometimes exceeded in current practice. There is also the alternative of using optical aids in these difficult cases, or devices for enhancing the material contrast. However, where such devices cannot, or will not, be used the illumination recommended for the efficient performance of some practical visual tasks must be very high.

Lythgoe (4) has pointed out that, up to 1,000 ft.c., there is a steady improvement in visual acuity, quickness of vision and colour perception; and probably a slight further improvement between 1,000 and 10,000 ft.c. Economic and technical considerations set the upper limit to artificial illumination, rather than any known property of the eye. Where high illumination is free, Lythgoe instanced its choice by the fine lace workers of Geneva, who take their work into the bright sun. The work of a number of other investigators has also shown the need for high illuminations for very fine work.

But, in deciding the upper limit of the code, the characteristics of the most difficult task for which provision need be made must be considered. So far as size is concerned, many practical tasks involve the discrimination of detail which subtends a visual angle of less than one minute. Ability to resolve detail subtending an angle of one minute is the criterion of "average normal visual acuity," and a practical code should certainly include the illumination necessary for

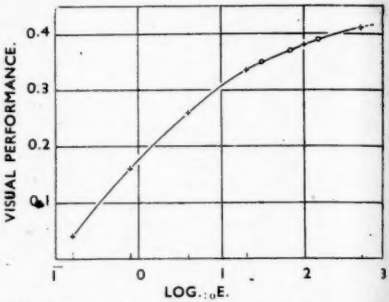

Fig. 3. The relation between visual performance and $\log_{10}E$. The apparent size of the critical detail to be seen is 1 minute. Contrast is black on white. Points indicated by small circles represent 85, 90 and 95% of performance at 500 foot-candles.

this to be done with a high degree of efficiency, namely, about 90 per cent. of the maximum possible speed and accuracy.

The investigation described in (2) showed this illumination to be about 60 ft.c. This is seen in Fig 3. The task resembled that of proof-reading and presented word-like groups of small broken rings, among which all those having the gap "wrongly" orientated had to be detected. It should be noted that the curve indicates that further improvement might be got at illuminations higher than the maximum of 500 ft.c. actually used. Even if performance is taken to be the absolute maximum at 500 ft.c., the ratio between illuminations for minimum

and maximum visual performances is greater than 1 : 3,000, and about 1 : 400 between minimum and 90 per cent. performance illuminations. The slope of the curve about the 90 per cent. performance point is such that a change of performance of only about ± 2 per cent. occurs for a change in illumination of ± one-third. This variation must be taken into account in considering suitable tolerances for recommended values of illumination.

The variation of performance with illumination has not been determined for sizes smaller than one minute, but from the relation between visual acuity and illumination found by Lythgoe ([5]), and the ratio to be expected between the illumination required for a threshold and a 90 per cent. relative performance, it is clear that, if size were the only factor to be considered, the upper code limit must exceed 100 ft.c. to cover fine work. The American code recommends illumination levels above 100 ft.c., but does not specify a definite upper limit.

8. Dividing the Range.

Within the necessary range of illuminations, and under laboratory conditions, the equal ratio increments corresponding with just noticeable differences of brightness are quite small. Under practical conditions, the ratio of change must be much higher for the increment of brightness to be effective in reducing the difficulty of a given visual task, or permitting the same relative performance with tasks which are ranked next in order of difficulty. In the case of fine work, as shown above, an increment of less than one third of the illumination which is already adequate for a relatively good performance is not of much practical value in further facilitating visual performance. This is also true with less exacting tasks, as can be seen from the curves of Fig. 4. These are plotted from the data published in ([2]). On the curves points are shown at which 85, 90, and 95 per cent. of the performance at 500 ft.c. occurs. These are percentages of the maximum possible performance of each task, with the exception of the smallest. With this, however, the probable improvement beyond 500 ft.c. can be neglected for the present purpose.

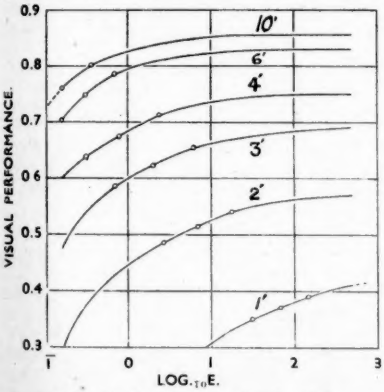

Fig. 4. The relation between visual performance and $\log_{10}E$ for tasks involving discrimination of detail of different size. Contrast is black on white. Points indicated by small circles represent 85, 90, and 95% of performance at 500 foot-candles.

With the easiest tasks, involving the two largest sizes, nearly maximum performance is reached at 2 ft.c., which has already been suggested as the code minimum illumination. In the case of smaller sizes, the relation between the logarithm of illumination and relative performance is such that the change from 85 to 90, and from 90 to 95 per cent. requires the illumination to be more than doubled in each case. The slope of the curves is not identical for each size, but it is sufficient to say that, on the average, relative performance is increased 5 per cent. by about a 2.6-fold change of illumination. A change of relative performance of from one to nearly two per cent. occurs (within the range 85-95 per cent.) for a change of 0.1 in $\log_{10}$ E. Thus, approximately a 26 per cent. increment of illumination is needed to improve relative performance by this small amount, and no smaller increment can be regarded as a practically effective illumination step.

In Fig. 5 the points corresponding with relative performance values of 85, 90, and 95 per cent. in Fig. 4 are plotted against the logarithm of the visual size of detail involved. Thus, the relation between $\log_{10}$ size and $\log_{10}$ E is shown for three levels of

relative performance. Above the lower limit of illumination which is of interest (2 ft.c.), it is seen that the relation is linear in each case, though the slope of the curve is steeper the higher the performance. The relation for RP=90 per cent. is $\log_{.10}$ E=1.845−3.24($\log_{.10}$ S), where S=apparent size of detail in minutes of arc subtended at the eye. From this it follows that if $\log_{.10}$ E is increased by 0.1, i.e., illumination is increased by 26 per cent., $\log_{.10}$ S is diminished by 0.0309, i.e., apparent size can be reduced by 7.4 per cent. Similarly, for an increase in $\log_{.10}$ E of 0.15 (increase in illumination of 41.4 per cent.), size may be reduced by 11.3 per cent. If illumination is doubled size can be reduced by about 24 per cent.

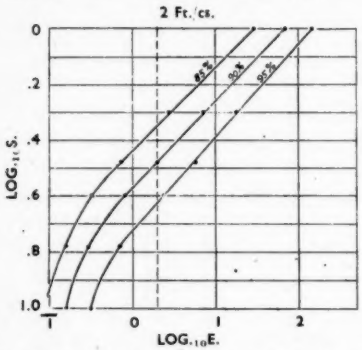

Fig. 5. The relation between $\log_{.10}$S and $\log_{.10}$E for three levels of relative visual performance. S = apparent size of critical detail (in minutes).

Now, to discriminate in practice between visual tasks which differ in the apparent size of detail they present by only about 7 per cent.* is not easy, and would involve much more precise assessment of tasks than has yet been made. Though the dimensions of detail in the visual object can be accurately measured, the distance between object and eyes, which determines the apparent size, is measurable with less precision. At present, it is probable that the best assessment of task difficulty that can be made will not justify the division of the code range into successive values whose logarithms differ by less than 0.15, that is, into a series of illuminations each of which exceeds the preceding value by 41.4 per cent. If such values are adopted, a mistake of one step in prescribing for a given task will affect its relative performance by less than ± 3 per cent. of the code objective. If the code range is divided into sub-ranges, covering more or less broad categories of tasks, the sub-range limits cannot be in lower ratio than 2 : 1, i.e., they must include at least two illumination steps, and $\log_{.10}$ E+0.15+0.15=$\log_{.10}$ 2E.

In order to check the conclusions drawn from Fig. 5, similar data have been derived from two subsequent investigations, the results of which have not yet been published. The graphs of Fig. 6 are plotted from the average results of all three investigations. The relation for RP = 90% is $\log_{.10}$ E = 1.806 − 3 ($\log_{.10}$ S), or E= 64/S^3. This gives an illumination of 64 ft.c. when the visual size is one minute. The data published in (2) indicate that this relation will not be valid for sizes much smaller than 1 min., but it will be assumed true for a size 20 per cent. smaller, for which the illumination will be 128 ft.c. This illumination need not be exceeded on account of size alone. When finer detail is to be seen much more is to be gained by the use of optical aids. Thus the total range required is from 2 to 128 ft.c. to permit a relative visual performance of 90 per cent., with tasks which present good contrast but differ in size.

The range consists of thirteen effectively different illuminations, forming a series whose common ratio is 1.414. It may be divided into six sub-ranges,

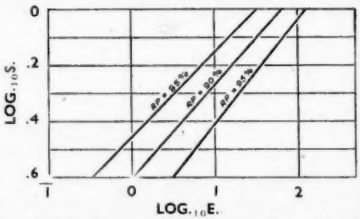

Fig. 6. The relation between $\log_{.10}$S and $\log_{.10}$E for three levels of relative visual performance. S = apparent size of critical detail (in minutes).

* The difference threshold for size is about 1 per cent.

whose limits have a common ratio of 2, if it is desired to classify tasks on a broader basis. The category limits then form the geometrical series 2, 2^2, 2^3, . . . 2^7 ft.c. Table 1 gives the serial illuminations and the corresponding visual angles subtended by the material detail of the task. The dimensions determining the visual angle are those of the object and its distance from the eyes and, for practical convenience, the quotient of the latter by the former is shown in column 6, with limiting values in column 7.

9. Correcting for Reflection Factors and Contrast.

The foregoing illuminations are related to the size of detail involved in the visual task, and apply only when the contrast inherent in the work is the best possible, thus in-

TABLE I.

Serial No. of E Value.	Log_{10} E *	Actual value of E	Practical value (E_W) lumens per sq. ft.	Visual angle of material detail.	Value of $D/S = \frac{1}{\tan \theta}$	Limits of D/S for E_W.	Serial No. of task category.
1	0.30	1.995	2.0	3.18′	1110	Up to 1175	1
2	0.45	2.818	3.0	2.83′	1250	1176 1325	1
3	0.60	3.981	4.0	2.52′	1400	1326 1485	2
4	0.75	5.623	6.0	2.25′	1570	1486 1665	2
5	0.90	7.943	8.0	2.00′	1765	1666 1870	3
6	1.05	11.220	12.0	1.79′	1980	1871 2100	3
7	1.20	15.850	16.0	1.59′	2220	2101 2350	4
8	1.35	22.390	23/24	1.43′	2500	2351 2650	4
9	1.50	31.620	32.0	1.26′	2800	2651 2970	5
10	1.65	44.670	45/48	1.12′	3140	2971 3330	5
11	1.80	63.100	64.0	1.00′	3530	3331 3740	6
12	1.95	89.130	90/96	0.89′	3960	3741 4200	6
13	2.10	125.900	126/128	0.80′	4440	4201 4700	6

D = distance in inches between eye and object.
S = size in inches/1000 of material detail, *e.g.*, diameter.

*As illumination levels are energy levels, the difference between any two values can, if desired, be expressed in decibels. The number of decibels between successive illuminations in the above table is ten times the difference of their logarithms, or ten times the common logarithm of the ratio that each value bears to its predecessor. Tnus there is an equal difference of 1.5 db. between each illumination and the next. Also, if the logarithms in column 2 are multiplied by ten they express the code illuminations in dbs. above a reference level of 1 ft.c. The range is then from 3 to 21 dbs. Any otner convenient reference level might be adopted, e.g., 0.01 ft.c., or approximately the photopic threshold. Decibels above (+ dbs.) the reference level would then be photopic illuminations, and decibels below (− dbs.) the reference level scotopic illuminations. On this basis the above illuminations extend from +23 to +41dbs.

volving maximum and minimum values of reflection factor. This condition will not always be satisfied in practice, so that the illuminations must be modified to secure the correct brightness level, and, if possible, compensate for inferior contrast. In this paper the term "contrast" has reference to the degree of objective unlikeness, either of colour or brightness, differentiating elements present in the task.

Beuttell (1) proposed to deal with contrast and the reflection properties of the object materials by means of a single correction factor, which leads to values of illumination such that all contrasts present the same absolute brightness difference, whose magnitude is determined by size of detail. The appropriate correction factor is $\frac{1}{\rho_1 - \rho_2}$, where ρ_1 and ρ_2 are the two reflection factors in contrast. Beuttell suggested a maximum value of 20 as a practical limit to this factor, and this, therefore, will apply to all contrasts that can be obtained with pairs of reflection factors differing by 0.05 or less. Without this arbitrary limit the value of the factor would reach 100, even if the worst contrast likely to be met in practice is assumed to be no poorer than one involving values of ρ_1 and ρ_2 of 0.05 and 0.04 respectively. With the limit, the maximum illumination obtained by correcting for the lowest contrast range is 20 ft.c., providing the size involved requires only the basic value of 1 ft.c. proposed by Beuttell. When, however, the size demands the maximum illumination provided for in Beuttell's paper, i.e., 10 ft.c., the maximum illumination found by his method for the worst contrast is 200 ft.c. This value is increased if multiplying factors for movement and emphasis are applied.

Beuttell's dual factor is derived as follows. The basic illumination is first "corrected" for the reflection factors involved, so that the highest of these is, in effect, made ideal. This is done when the basic illumination is multiplied by $1/\rho_1$. A further correction is then made to vary the illumination inversely with the contrast, and in such a way that B_1 is always greater the poorer the contrast, while $B_1 - B_2$ is constant, and therefore independent of the contrast. This is done when $E_b \times 1/\rho_1$ is multiplied by the reciprocal of the contrast. For this purpose contrast is evaluated as the ratio $\frac{\rho_1 - \rho_2}{\rho_1}$. E_b is thus multiplied by $1/\rho_1 \times \frac{\rho_1}{\rho_1 - \rho_2} = \frac{1}{\rho_1 - \rho_2}$. Thus, though this factor is not a function of contrast, i.e., is not bound to vary with contrast, it enables the two corrections described to be made by a single factor.

The effect of this factor in making $B_1 - B_2$ independent of contrast has no significance in itself, since it effects no change in the objective unlikeness of different contrasts, as defined by B_1/B_2. The significant effect is the inverse variation of the brightnesses according to their ratios, so that inferior contrasts will always have superior brightnesses. To this extent the method is a valid one which can be shown to reduce, though not eliminate, the difference of performance of visual tasks, differing only in contrast, which occurs when correction only for ρ_1 is made. Applied to the basic illuminations determined for size, instead of to Beuttell's tentative values, it can give extremely high illuminations. Thus, for a size of 1′ the basic illumination is not 10, as Beuttell assumed, but 64, so that in the case where $\rho_1 - \rho_2 = 0.05$ the illumination required is 1,280 ft.c.

If correction is made for ρ_1 alone, by applying the factor $\rho_1 \text{ max}/\rho_1$, very high illuminations can also be obtained. Giving ρ_1 max. the value of 0.09, and taking the lowest value of ρ_1 as 0.0375, the correction factor has a maximum value of 24. If the size involved is 1′ and ρ_1 is 0.0375, then $E = 64 \times 24 = 1{,}536$ ft.c.

Logically, the correction for ρ_1 should be rigorously applied. But it is obvious that practical considerations will require some arbitrary limit of correction to be fixed, if a correction is also to be made for contrast. A maximum illumination of 128 ft.c. has been proposed on account of size, and it is now proposed that

the correction factor for ρ_1 and/or contrast should have a maximum value of 10, so that the code maximum illumination will not exceed 1,280 ft.c. There will then be only partial correction for ρ_1 when it has a value smaller than 0.09, and no correction then for contrast. There is, however, no reason why higher values

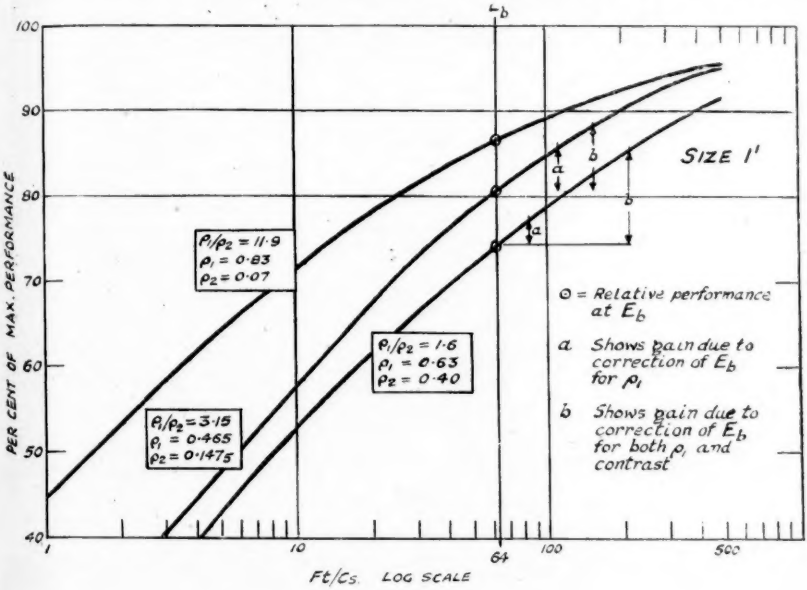

Fig. 7.

of the factor should not be used when size requires only moderate illuminations.

In Fig. 7 the effect is shown of (a) correcting E_b for ρ_1 alone, and (b) correcting E_b for both ρ_1 and contrast. The curves of Fig. 8 refer to different contrasts having the same value of ρ_1, and thus show the effect of correcting E_b only for contrast. The application of the dual correction in the particular cases to which Fig. 7 refers, is seen to yield approximately equal relative performance with each contrast, i.e., it makes relative performance almost independent of contrast. This is not generally true, though it always reduces the handicap of inferior contrasts. For the cases illustrated in Fig. 8 equal relative performance is not secured, but the improvement in this direction is roughly proportional to the correction applied for each contrast.

It should be noted that where the illuminations required to correct for poor contrast and low reflection factors are high, it is not merely expedient to obtain them by supplementary local lighting, but essential they should be so obtained. Otherwise, the relation of field to work brightness would be unsuitable. The highest values of illumination visualised can be obtained economically by suitably designed local lighting units. Nevertheless, the use of very high illuminations may require the development of new lighting units, having narrow and well controlled distributions with, perhaps, some provision for varying the distribution to suit different applications. For some tasks the proper method of supplementary lighting is literally spot-lighting. It must be

emphasised, however, that a foundation of general lighting is always necessary in lighting for work. And so many practical tasks involve dark materials that it is probably desirable, in a code, to specify a minimum as well as a maximum ratio of work to

ensuring that these are taken into account is to read the required illumination from a suitably prepared graph. This is shown in Fig 9, and is self-explanatory.

It should be borne in mind that the illuminations derived in this way are

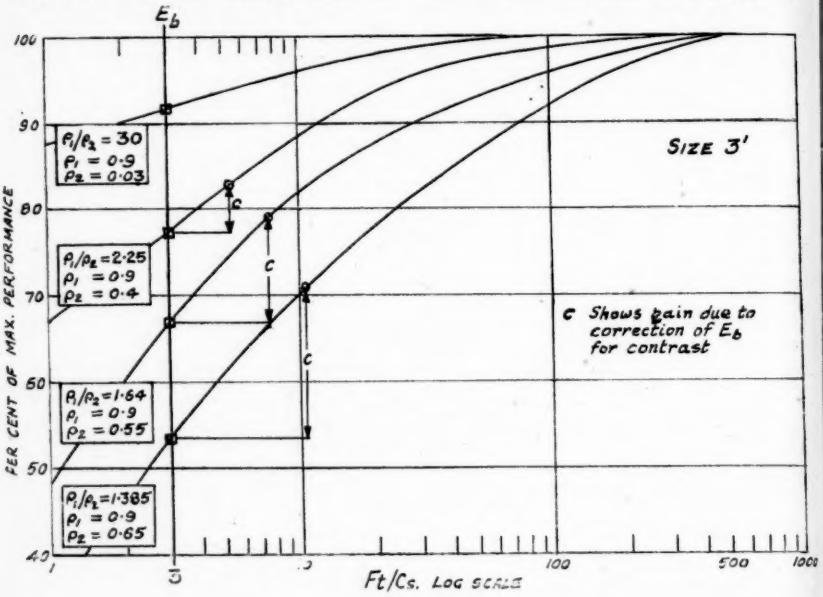

Fig. 8.

field brightness. Two and twenty may be suitable values.

10. Finding the Required Illumination.

The proposals discussed can now be summarised in a formula for computing the working illumination required as follows:—

$$E_w = \frac{1}{\rho_1 - \rho_2} \times \frac{k}{S^3} = \frac{k}{S^3(\rho_1 - \rho_2)}$$

The value of k, when $\rho_1 - \rho_2$ has a value of 0.87, has been shown to be 64. For the ideal case, in which $\rho_1 - \rho_2 = 1$, it must be reduced to 64 x 0.87 = 55.68, so that

$$E = \frac{55.68}{S^3(\rho_1 - \rho_2)}$$

The use of this formula is, however, subject to the limitations discussed in the paper, and the simplest way of

orders of illumination rather than critical values, and a tolerance of plus or minus one-third is permissible. But, subject to this qualification, recommended illuminations should always be stated as single values—as are dimensions in general engineering practice.

It is proposed that future I.E.S. practice should follow this method, so that items in the detailed list of recommendations will be stated thus—

	Foot-candles.
Medium bench and machine work	8 — 12 — 16

or

	Foot-candles.
	$\pm 33\frac{1}{3}\%$
Sewing light materials	12

As illumination is defined in terms

of surface density of luminous flux, it is also suggested that "lumens per square foot" should be substituted for "foot-candles," in spite of the fact that the latter term has become so well established. Brightness can also be specified in lumens per square foot, as is done in the Australian code, and the simplication effected by the use of one easily understood unit for both purposes would be of particular advantage to non-technical users of the code.

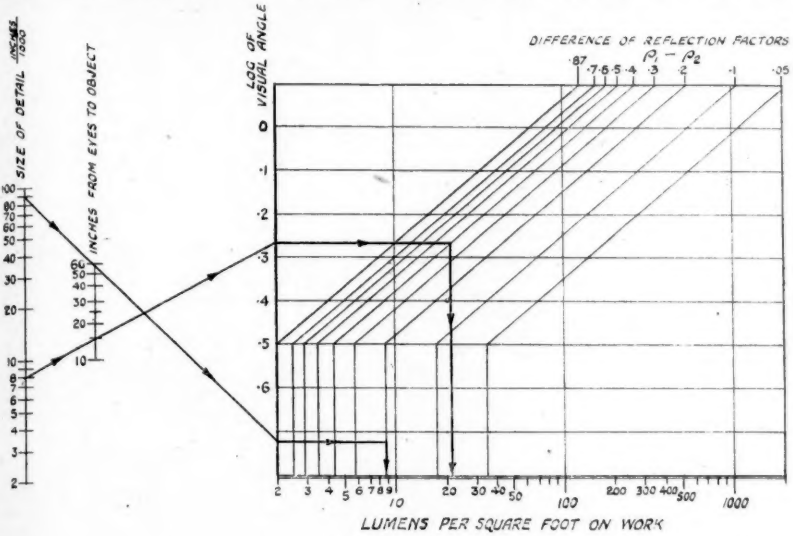
SIZE OF DETAIL
INCHES FROM EYES TO OBJECT
LOG OF VISUAL ANGLE
DIFFERENCE OF REFLECTION FACTORS
$\rho_1 - \rho_2$
·87 ·7 ·6 ·5 ·4 ·3 ·2 ·1 ·05
0 ·1 ·2 ·3 ·4 ·5 ·6
100 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3 2
60 50 40 30 20 10
2 3 4 5 6 7 8 9 10 20 30 40 50 100 200 300 400 500 1000
LUMENS PER SQUARE FOOT ON WORK

Fig. 9.

11. Agreement with Current "Good Practice."

Close agreement between illuminations computed in the manner described and those of current "good practice" must not necessarily be expected, though it is likely to be found in numerous cases. In others, however, more accurate task assessment will show the need for current recommendations to be revised. Where a value for a practical task has been determined experimentally, and is unaffected by the—often superficial—economic considerations that influence practice, the new method can be expected to yield a value of the same order. This is so in the case of type-setting by hand, in which the "copy" forms that part of the task requiring most frequent visual discrimination.

12. Applying the Code.

Careful analysis and measurement of the task is, of course, the essential preliminary to the application of the code. It will not suffice to assess the task broadly as fine, medium, etc. But, as analyses are made, and the appropriate illuminations computed, processes can be listed with their recommended values, as is now done. If the proposals in this paper are adopted, the existing I.E.S. classified list of processes will, in fact, be retained and, for the present, the recommended illuminations will merely be brought into line with the new code steps. This involves no immediate radical change, but from time to time, as the necessary data become available, revision of the recommended values will be necessary in some cases. At the outset it was recognised that difficulties will be encountered in analysing practical tasks. All of these cannot be foreseen and dealt with here. But if, at first, the analytical method of diagnosis is used only

where it is easy to apply, there are many cases which can be dealt with in this way.

There should be little difficulty in measuring ρ_1 and ρ_2 with sufficient accuracy, using a simple grey reflection factor gauge. Similarly, the reflection factor of coloured surfaces is not difficult to assess. Where contrast is not due to a difference of colour or reflection factors but to shadow, the greyness of the shadow must be matched to find the value of ρ_2. Colour contrast may be less easy to deal with, since, as is well known, good colour contrast may be presented by different colours having the same reflection factor. It will, therefore, be necessary to match the colours with samples of known reflection factor to determine which is the better—if they differ,—and also to determine the equally good grey contrast by comparison with a simple grey-contrast gauge. From the observed value of ρ_1, and the ratio of reflection factors in the estimated equivalent grey contrast, the appropriate value of the factor $\frac{1}{\rho_1 - \rho_2}$ can be calculated.

It is $\frac{1}{C\rho_1 - \left(C\rho_1 \times \frac{G\rho_2}{G\rho_1}\right)}$.

The validity of this method of correcting for colour contrast has not been established by experiment, but it seems reasonable to assume that it would give satisfactory results. In determining visual size the minimum distance between eyes and work should be taken as ten inches, even if it is observed that a shorter distance is actually used. To avoid eyestrain, the illumination must be sufficient for the material detail to be discriminated at least at this distance, and with nearly maximum speed.

13. Conclusion.

In this paper an attempt has been made to apply some of the results of recent research in the reconstruction of the I.E.S. code on a more satisfactory basis. Some of the proposals made have already been accepted by the Panel appointed by the Council to consider and report on this matter. They are put forward now for general discussion and criticism.

References.

(1) Beuttell, A. W. "An Analytical Basis for a Lighting Code." ("Illuminating Engineer," Vol. XXVII., Jan., 1934.)

(2) Weston, H. C. "The Relation between Illumination and Industrial Efficiency. 1.—The Effect of Size of Work." (Joint Report of the Industrial Health Research Board and the Illumination Research Committee, H.M.S.O., 1935.)

(3) Adams, S. "The Effect of Lighting on Efficiency in Rough Work (Tile Pressing)." (Joint Report of I.H.R.B. and I.R.C., H.M.S.O., 1935.)

(4) Lythgoe, R. J. "Visual Perceptions Under Modern Conditions." (Trans. I.E.S. (Lond.), Jan., 1936.)

(5) Lythgoe, R. J. "The Measurement of Visual Acuity." (Medical Research Council, Special Report Series, No. 173, H.M.S.O., 1932.)

"Recommended Practice of Industrial Lighting." (Trans. Illuminating Engineering Society, America, Vol. XXXIV., No. 4, April, 1939.)

"Australian Standard Code for the Interior Illumination of Buildings by Artificial Light." (Emergency Code No. (E) CA, 501-1942, Standards Association of Australia.)

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DISCUSSION

Mr. A. W. BEUTTELL, after paying a compliment to the author for the colossal amount of work he had done on this subject, said he wished to speak not so much on the technical side of the matter as on the question of utility. The whole idea of the work dealt with had been to get a more scientific background for the kind of code that had hitherto existed. To work that out and to prove it, or otherwise, needed a great deal of research. Much of that research work had now been done, and although more was required, it was not so important as what had already been done. In order to achieve the early establishment of a code —which could never be a matter of exact science—he felt it was better to have something which was as exact as it could be for the time being rather than nothing. There was one point with regard to the author's work which deserved attention—and which had his admiration—and that was the new and ingenious element of percentage performance. With regard to relative performance, the author had chosen the percentage of 90 per cent; but he rather felt it would be better to have a sort of sliding scale so that a higher percentage could always be taken if it were easily available. However, he might have interpreted the author's views on this wrongly.

Coming to the question of utility, he said he imagined the task would be approached somewhat in the following manner. It was not possible to have a numerical code which could cover every individual case. Code values would be set up for what might be termed the well known task, but a formula would be available for the man who could not find his case in the code, or who had some special problem, or who wanted to check it, or where there was some legal argument. From that point of view the method would be useful both as a scientific background and also for the man who had a particular problem to work out.

With regard to the question of noticeable differences, most people had subscribed to the idea that inasmuch as the least noticeable difference in brightness was always fairly considerable there should be groups which were fairly wide apart. That was quite true under the existing system of arbitrary grouping, but if there were a scientific method of getting a closer approximation he saw no reason why it should not be applied. Allied to that was the objection that two men in working out exactly the same problem might view their data rather differently. One man might take one detail of a job and the other another and get different results. He felt that was not an unsatisfactory state of affairs. It only meant that one was taking a different view of what he wanted to do from the other and naturally got a different answer.

Dr. J. W. T. WALSH joined with Mr. Beuttell in paying tribute to the excellence of the author's experimental work on this subject. He had been associated with it and had closely followed it throughout, so that he knew what exceedingly difficult work it was. He said that he had, however, to confess that the application of these results to the arrangement of a code of lighting values for different tasks still rather appalled him. In his view the most valuable part of the paper was the emphasis it placed on the geometrical or ratio scale. Personally he felt that illuminating engineers would have to line up with acoustical engineers and adopt a system of units which rose, not by a constant increment, but in constant ratio. Such a system would make the task of the illuminating engineer much easier in trying to deal with the problems the author had discussed. He felt it could be said that the author had "sold" them the idea of geometrical progression in the lighting code, but when it came to putting a particular task into a particular range of values, then he confessed he was rather appalled at the difficulties. There were two examples he could mention to illustrate what he had in mind. The first was the weaving of self-coloured materials having respectively a fine and a coarse count. Assuming everything else remained the same, it would be easy to find the particular illumination values which would enable these tasks to be carried out with equal facility, but he would be a very bold man who would, in actual practice, instal these two different values of illumination over the areas of the weaving shed devoted to these particular tasks.

The second example he mentioned was a comparison between reading black type on white paper, and sewing with a self-coloured thread of a particular reflection factor. In the case of the latter, it would be the size of the thread which would govern the visual angle; but in the case of reading, what would govern the visual angle? Would it be the thickness of the strokes of the type, would it be the over-all size of a particular letter, or what would it be? This was a very important point because in reading one did not examine the detail of the individual letter. One hardly examined the detail of the individual word. One

usually took in a group of two or three words which were familiar in appearance, and familiarity considerations might have a considerable effect on the illumination needed.

The author had pointed out that the illumination would affect only that portion of the task which depended on visual performance and had mentioned a task where half the time was taken in visual performance and half in manual operation. In arriving at his overall performance percentage in this case, however, he had left the visual performance at 90 per cent. so that the overall performance was higher than that attained in a task where the effect of visual performance was more dominant. Was this justifiable or should the visual performance be allowed to fall (to 80 per cent. in the example given) so that the overall percentage remained at 90 per cent.? This might be justified on economic grounds.

Finally, Dr. Walsh said he was horrified that the author should suggest expressing brightness in lumens per square foot. No doubt his suggestion was to express the brightness of any surface, viewed in a certain direction, in terms of the lumens per square foot emitted from a *perfectly diffusing* surface of equal brightness, but this would only lead to confusion because brightness was a luminous intensity per unit area and not a flux per unit area. It was for this reason that the name "footlambert" was preferred to "equivalent foot-candle" which gave the impression that brightness and illumination were two aspects of the same thing whereas they were fundamentally distinct.

Mr. HOWARD LONG said it was commonly known that illumination could be increased and conditions made very much worse by shadow contrast, and better results could be obtained by reducing the illumination and screening off the offending source of shadow. Running through the paper was an apology for not being able to do what they would like to because of economic considerations. If it were decided to water down the code for this reason they should take their courage in both hands and say that it had been done.

The general idea with regard to the code at present was for general illumination levels, but the paper stated that the whole of the work was based on the illumination of the visual task, which was a very different thing from the general illumination level. It was quite easy to provide an illumination of, say, 20 ft.c. in the working area before the plant had been installed, but what was the illumination on the visual task? There were astounding differences.

Then there was the question of the minimum value, and there were many cases in which it was necessary to go to much higher levels (for seeing) than those prescribed by the Factory Regulations, because the latter were formulated to provide background brightness. Remarking that it did not seem logical that a fundamental code should be proposed which wobbled about and had no sure foundation, and pointing out that it was the brightness on the task and not the illumination that mattered—in this connection, he suggested that the Table at the end of the paper should be clarified in the final edition—Mr. Long emphasised that the code did not propose any radical change, but only that the whole thing should be on a scientific basis and that the values should be brought into their respective compartments for the various tasks on a regular basis instead of on a hypothetical and arbitrary one.

Mr. H. E. CHASTENEY, commenting on the fact that the author had in mind the framing of a lighting code as a basis of legal requirements, recalled that Sir Duncan Wilson's Committee had considered this aspect in 1938, but decided that they were not then in a position to make recommendations on these lines. This paper would be welcomed because the author, by setting out the considerations on which a scientific code should be founded, had taken a valuable step towards the prospect of being able to formulate legal requirements. Industrial processes were so many and diverse and variable that to lay down a comprehensive legal standard by schedule of processes was a matter of great difficulty. What was wanted was something as simple and as definite as possible, so that "occupiers" should know exactly what were their duties under the regulations. There was also required some easy test of whether the law was being carried out, and there must be some ready way of deciding between contesting parties. Could the author say whether it was beyond the wit of man to devise some instrument for this purpose? It seemed that an instrument was required which would take into account the intensity of the illumination, the reflection factor, colour contrast, etc. Such an instrument would simplify the problem immensely in the application of regulations. Finally, he pointed out that Table 1 in the paper referred to angles of critical detail. Could the author say

in what way they could be applied to such a process as razor-blade grinding?

Dr. W. D. WRIGHT gave his comments with regard to the code from the academic, non-commercial point of view. It was obviously desirable that any code should be based on the illumination really required, and not on what the supply companies were in a position to provide. If a really high illumination were desirable, it was better to say so, even though the level was for the moment beyond attainment owing to economic limitations. Previously, code values had appeared to be determined more by what it was felt the general public and the commercial interests were prepared to pay for, and once one level had been reached the stakes had, as it were, been raised again. This savoured too much of "softee, softee, catchee monkey."

The author's adoption of a 90 per cent. performance level for reference purposes seemed to him to be sound practice, even though the maximum performance limit must inevitably be uncertain within perhaps 1 or 2 per cent. He agreed with Mr. Weston that a logarithmic scale of illuminations was desirable, although he could not follow the argument by which Mr. Weston had reached that conclusion. If he understood the argument correctly, Mr. Weston maintained that if tasks were subdivided into degrees of difficulty, with equally noticeable differences of difficulty separating each grade, then the illuminations required to secure equivalent performance at each grade of task would also be separated by equally noticeable differences of illumination. Surely, if this were so, it would mean that a linear relation between difficulty of task and compensating illumination must exist, whereas, so far as he was aware, no relation of any sort had yet been established, let alone a linear relation.

He felt some trouble might arise in applying the code to a factory in which operations involving different sizes of object were performed in the same building. This might lead to individual glare spots, so that it was important not to use the code piecemeal, but to design the lighting system as a whole and in relation to the illumination levels in other parts of the factory, especially when there was much movement from one part of the factory to another.

In regard to the effects of contrast, the value of the data given by Mr. Weston would be greatly enhanced if he could give more information about the nature of the objects and the quality of the contrast he had used in carrying out his experiments. This is important, since the application of the data, which is in any case likely to be difficult, will almost certainly depend on the type of work. Thus, in the case of sewing, for which part of the field of view would the contrast have to be calculated? Was it the thread of cotton against the background of cloth, or did the needle enter the calculation, or perhaps the shadow of the needle? In the case of small objects, the calculation of the contrast merely from the physical reflection data of the surface was likely to be in error, owing to aberrations in the optical system of the eye, which would tend to reduce the contrast.

Mr. F. C. SMITH said he would like to ask the author for some further details in regard to the investigations which had led to the results given in the Paper. He assumed, for instance, that a definite task had been carried out by a large number of people and the subjects had performed this task at various levels of illumination. It would be useful if the author would indicate the time for which the subjects worked at each illumination level. Was this time, for instance, very short, extending over, say, half-hour, or did it correspond to a time which would be comparable to the continuous effort the subject had to make in the everyday work of the factory? He thought the author would agree that the factor fatigue might come into this matter in a way which was perhaps not directly related to the relative times. He, for example, had experienced the benefit of high illuminations when doing exacting tasks, which had to be carried out for a relatively short time, but when these tasks were continued at these high illuminations for very long periods fatigue, of course, was experienced. He thought that this fatigue was not solely due to the continuity of the work but was in some way related to a secondary, and at present ill-defined, effect which was not unrelated to the very high values of illumination. Perhaps the subject who said he liked a "restful light" was trying to put into words this experience. The reality or otherwise of this secondary effect could only be investigated if the tasks were carried out over a period which corresponded to that usual for continuous working in factories.

Another point which is, in fact, closely related to the one previously mentioned is as follows: Assuming two subjects were working at a task and both

achieved the same results under similar conditions, it was probable that one would experience more fatigue than the other. Had the author any means of measuring the increased nervous strain imposed on one as compared with the other? He knew that all sorts of methods had been tried out in America by various observers and that the problem was extremely difficult. He raised it here, however, rather to indicate that in using curves of performance one should always bear in mind that curve of equal performance were not curves of equal effort, nor did it follow that the relationship between increased performance with increased stimulus was similar to that which related fatigue with stimulus.

In general, he agreed with other speakers that it was difficult to analyse the task, but he felt that Mr. Weston had done a great service. At present we were very largely dependent upon established good practice, but now surely there was emerging a more scientific basis upon which to assess the requirements for any given task, and he would like to congratulate Mr. Weston on the very fine work he had been able to accomplish.

Mr. IMRIE-SMITH, speaking on the difference that usually existed between the average general illumination and the actual illumination on the work, recommended that it should be made plainer than it is in the present code as to which of the two values was intended.

Referring to the proposed calculations for assessing the requisite illumination for a particular task, the important part played by reflection factors should be carefully considered. From the visual point of view, the reflection factor was practically valueless, it being necessary to know not only how much light was reflected, but how it was distributed. This leads to vital complications as to the relative positions of the eye, the object, and the light source, if one is to assess the resultant visibility. Even if it were possible to make some allowance for this the results would be very much of a laboratory nature and would necessitate an appreciable latitude.

He was rather surprised at the proposal to state a definite illumination value for a process instead of giving limits. Whilst a number of people regarded "anywhere within the limits" as good enough, he, personally, had regarded the latitude given as a concession that it was impossible to specify correctly a definite illumination without taking into consideration the conditions of the particular case. Differences in machine types, whether the grade of work was near the finer or rougher end of its category, all made a difference, and it certainly seemed desirable to clearly maintain this impression of latitude.

The PRESIDENT asked whether, in spite of the many difficulties which had been raised with regard to the code, it was not possible straightaway to visualise a great improvement in our present technique by standardising general lighting, as distinct from local lighting, for the lower ranges up to 40 or 50 ft.c. The author, quite reasonably, had dealt in the paper with extremes, but it was in dealing with extremes that the greatest difficulties arose. What could be called arbitrary and expediency factors in the lower ranges might be excluded, and this should enable the use of really correct factors for some of the tasks that were at present in the lower levels. Supposing the size factor was A, the reflector factor was B, and the contrast factor was C, one would only bring in these special factors when $A \times B \times C$ exceeded or was less than a certain figure. Moreover, how was the size factor to be determined? In the case of hand-fitting a pinion it might be necessary to file it down to a tolerance of .001 in. in one case, and to .0001 in. in another case. Again, was any distinction made in the contrast factor when the object being worked on was brighter than its background and when it was darker than its background?

Mr. H. C. WESTON, replying to some of the principal points raised in the discussion, referred to what had been said as to the difficulty of applying the method described. He quite appreciated these comments and, indeed, in more than one place in the paper had emphasised it himself. However, he was not prepared at the moment to analyse particular tasks and to say just what was the material detail involved. That was something which the illuminating engineer would have to do if he adopted a method of prescribing illumination such as the one proposed. The illuminating engineer would have to make a detailed study of the tasks involved, in order to determine just what was the critical detail to be seen. Unless it was felt that the difficulties involved were insuperable, their existence at the moment did not seem to invalidate the method as such. He would not attempt to give a detailed answer to what Dr. Walsh had said, but he would mention an example which might be helpful. Take the case of the sewing needle; it would be wrong to take the size of the eye of the needle. It was necessary to see when the eye of

the needle was almost obliterated, i.e., when the cotton was nearly in, so that there was practically no hole to be seen. A similar case existed in many industrial operations. There was, for example, the insertion of pivots in the busnes of small moving coil instruments. He had asked an operator what was the smallest object he had to see, and got the reply tnat it was the hole in tne bush into which the pivot was inserted. The size of that was 0.02 of an inch. From this a basic illumination of 2 ft.c. should suffice, but, in fact, this would be ridiculous for that task. What had to be seen was not the complete hole, but almost its absence, because when the pivot was positioned so that it could safely be inserted there was practically no hole visible. This example emphasised the difficulties involved before any such method as that described in the paper could be applied. Something would have to be done to help illuminating engineers make these analyses, and he was hoping that some actual examples could be taken and analysed so that it could be seen whether the method would work out reasonably well or whether it was quite impracticable. There was no reason, as Mr. Beuttell had suggested, why a precise value should not be taken, providing it was always understood that it was not critical. Wide tolerances always had to be assumed, but it seemed very much better to state the precise value in the code, because misconception could so easily arise when one was talking to people who were buyers of illumination. If they were given a range they would always tend to use the lower value. The difficulty of administering regulations had been mentioned by Mr. Chasteney, who had also put forward the attractive idea of devising an instrument which would indicate the illumination required. Attempts in that direction, however, had not so far been very successful. It was difficult to see how such an instrument could be devised. The difficulty of providing for many processes carried out in the same room would always exist, and all that could be done was to plan for what might be regarded as the average kind of work, except, of course, that supplementary local lighting was always possible, and was now used wherever very fine work was carried out. In reply to Mr. Smith on the nature of the tests that had been carried out, he said they were not carried on for ordinary periods of work, and it was probable that the fatigue factor would be noticeable in longer periods than were occupied by the tests. The result would be that the whole curve would be displaced vertically downwards, but he did not think that would alter the relative performance relation.

Owing to the lateness of the hour, the author said that in the printed version of the discussion he would deal with other points which had been raised.

FURTHER COMMENTS (communicated): With regard to the examples of visual tasks mentioned by Dr. Walsh, in the case of the weaving shed it might, in practice, be most convenient to provide the mean of the two values of illumination instanced, and thus accept a sub-standard visual performance of the "finer" task, but getting a higher standard with the "coarser" task. But if certain areas in a shed are regularly devoted to weaving fine and coarse "counts" respectively, there seems no good reason why different illuminations should not be provided, so long as a very large difference is not involved. Alternatively, supplementary local lighting should be provided for the fine work, as is necessary in many other cases.

In reading, it is true, as Dr. Walsh points out, we do not examine the detail of individual letters, but habitually rely on familarity and the general appearance of whole words, or even groups of words. But is it really legitimate to take advantage of this to provide less illumination than is needed to permit easy discrimination of the detail of individual letters? Failure to make this discrimination may sometimes have serious consequences, particularly when figures are read. The detail to be seen is that which differentiates one letter or figure from another for which it might be mistaken. For example, the gap present in C and 3, but absent in O and 8. Taking the visual angle from this, and taking contrast into account, the illumination required for reading war-time newsprint, works out at about 5 to 6 ft.c. It will be rather less for ordinary book reading, but about 10 ft.c. for technical books using small figures and mathematical symbols.

This is not inconsistent with experience and general opinion as to what is a "reasonably good reading light." The illumination is much higher if a very close approach to maximum visual performance is desired. In this connection it is interesting to recall the observations made by E.L.M.A., using the method of choice, and using newsprint as test material. On the average the illumination chosen was about 100 ft.c. (vide E.L.M.A. Handbook, No. 1a). Although objections can be raised to this type of experiment, the method of

choice aims to determine the optimum value—that which gives maximum performance;—and, in its relation to the calculated value given above, the E.L.M.A. result is consistent with the results of the D.S.I.R. experiments. This supplements the evidence in Section 3 of the paper on the expediency of fixing the standard performance at about 90 per cent.

Dr. Walsh suggests that when visual performance is an important factor only for part of the working time, it might be allowed to fall below 90 per cent. This might be justified on economic grounds, and it may be emphasised here that the proposed method is primarily intended to give values for pure visual tasks. These form the basis upon which the lighting engineer can proceed to exercise his discretion before arriving at a final recommendation. It may be justifiable to scale down the basic value, for example, in the case of semi-mechanised processes, or to increase it when it is very low, and a higher value, giving a better performance, would be worth while,—or in circumstances for which Mr. Beuttell proposed the application of an "emphasis factor."

In the work on contrast, to which Dr. Wright refers, test sheets were used, similar to that illustrated in (2), but having the Landolt rings printed in different shades of grey. In the case of sewing, the contrast might be between the thread and fabric, or between threads of the fabric and intervening gaps—as in mending,—or contrast between needle and fabric may be important. Calculation of the contrast from the physical reflection data of the elements involved will admittedly give values whose error may vary with size, but no better method suggests itself.

Mr. F. C. Smith mentioned his experience of fatigue when working for long periods with high values of illumination. That this was related in some way to the illumination itself seems doubtful. Probably he would not have this impression in daylight with similar, or even higher, illumination levels, and it seems more likely that any effect of the kind mentioned would be due to other characteristics of the lighting. Special care is necessary to avoid glare when high values of illumination have to be used, and this was taken when making the experiments referred to in the paper. There is, unfortunately, no easy and direct method of measuring the fatigue, or nervous strain, involved in doing work.

Mr. Imrie-Smith's objection to the specification of single values instead of ranges of illumination is met, in the paper, by the proposal to qualify these values by stating the permissible tolerance, as a fraction or a percentage. Thus, while a definite "target" figure is given, the latitude is also defined, but is constant and equal to the widest latitude allowed in the current code.

Regarding the President's suggestion for the standardisation of general lighting up to moderately high values, if this is meant as a "solution by surplus," no doubt task analysis could be restricted to extreme cases. As the cost of lighting falls, this method—which is Nature's own—may be more readily adopted. It is often used now for values up to about 20 ft.c., and a vast number of tasks could be adequately provided for by such a system. The number of obviously "fine" and "very fine" visual tasks, for which careful analysis should be attempted, is considerable, but there are many more for which it will be unnecessary, and which experienced lighting engineers should have no difficulty in assigning to one of the first three categories of the code. The questions asked about the application of the code to special processes show, however, how little is known about the real visual task presented in these cases, and the need for analysis to provide the illuminating engineer with essential data.

Mr. STUART D. LAY, in a communicated contribution since received, urges that great care would be needed to prevent the method being misapplied by inexperienced people, especially where multiplying factors for low brightness or contrast are concerned. He agreed that only trained persons should deal with the problems covered by the code; for others a code specifying brightness instead of foot-candles would be preferable. The difficulty of assigning a critical visual angle to every task is a very real one, complicated by the help or hindrance of the surrounding visual pattern. He would like to hear Mr. Weston's views on the application to his work of such apparatus as the Luckiesh-Moss visibility meter. The recommendation of a minimum ratio work/field brightness would be a great step forward. The conception of emphasis is necessary and overdue, though the implementing of this recommendation would doubtless frequently present difficulties.

Mr. J. MITCHELL, in opening the discussion of Mr. Weston's paper, read before the Newcastle Centre (North-Eastern Area) on February 3, remarked that these standards were not based on any comparison of artificial light with daylight. Yet it was well to keep the impression of "daylight seeing" at the back of one's mind. The actual "power of seeing" gave a logical basis for the gradations of a Lighting Code, assuming the necessary minimum illumination, which varied with the difficulty of the task. Mr. Weston had done very good work in charting this field. As instances of problems involved in this new process Mr. Mitchell mentioned difficulty in defining the detail, the distinction between "visual acuity" and "visual perception," and the treatment of detail which is not confined to a single plane. In conclusion, Mr. Mitchell emphasised that other factors (absence of glare, diffusion, etc.) must be considered as well as adequate illumination in foot-candles.

LIGHTING AND POST-WAR RECONSTRUCTION

(In what follows we present a summary of communicated contributions to the discussion of the paper by Mr. A. G. Higgins on the above subject read on December 8th, 1942.)

Mr. P. J. WALDRAM remarked that reconstruction is impossible without legislation, which must be administered by public officials. The Society must be prepared to frame and advocate standards of natural and artificial lighting, or to leave this matter in the hands of officials, possibly preoccupied with work of higher priority.

Post-war legislation would be mainly confined to enforcing standards of reasonable adequacy, not of Utopian ideals. There was, however, a tendency to "play for safety," and to quote desiderata rather than essentials. In this connection Mr. Waldram referred to the proposed standard of 5 per cent. for the standard of minimum daylight in factories, mentioned in a paper read before the Society last session. Yet many years ago an I.E.S. Committee found that in modern elementary classrooms visited, with generous high windows, often facing into wide and almost unobstructed playgrounds, the daylight factor on the desks furthest from the windows was of the order of 0.5 per cent. only. Mr. Waldram also criticised a recent statement that increase of lighting efficiency per unit of area of unobstructed glass with increased height of window was reversed at 30° elevation. The results of an investigation published in *The Builder* this year indicated that the critical angle was 45°. As this angle was never reached from the backs of rooms of ordinary proportions the old rule of taking up window heads as near to the ceiling as practicable still held good.

Mr. Burnett's citation of the arbitrary twenty years of prescription required to establish rights of light was timely. Such rights formed a fortunate survival of the old Roman law of light. Nearly a quarter of a century ago he advocated that rights of light should be made communal instead of merely personal. This could be done now, without injustice or difficulty, by Parliament insisting that each local authority should submit for approval a scheme under the Town and Country Planning Act, 1932; or, in default, to have one imposed on them by the M.O.W.P. He urged on the Society that it should advocate this vital reform.

Mr. J. B. CARNE expressed general agreement with the views of Mr. Higgins in regard to the approach of better lighting conditions in the post-war era. He was, however, concerned at the apparently discouraging prospect envisaged in his remarks of the present and future lighting in schools by Dr. Savage—who seemed to have made out a "cast-iron" case for better lighting! He (Mr. Carne) wondered whether Sir Arthur Whitelegge and his pioneers were spurred on or deterred from pressing for factory lighting legislation by the appalling conditions in a great proportion of the factories in the early part of the century. He imagined that the dames' schools and privately owned schools were on a par with the worst lit factories of the past. No doubt much education and exemplary demonstration would help towards the conditions in such schools up to reasonable standards. But our experience in regard to factories should show that general advancement would be most surely attained by legislation.

SESSION 1942-1943

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Mr. S. I. Ellis (Newcastle-on-Tyne)
Mr. J. T. Grimshaw (Sheffield)
Mr. Edward Jones (Cardiff)

Hon. Treasurer :—
Mr. H. C. Weston (1942)

Hon. Secretary :—
Mr. J. Stewart Dow (1928)

The names in italics are those of retiring Officers or Members. The date in parentheses after each name indicates the date of election to Office or Membership of the Council.

ELECTION OF OFFICERS AND COUNCIL

SESSION 1943-1944. OFFICIAL NOTICE

IN accordance with the procedure specified in the Articles of the Society, a list of existing Officers and Members of Council, of vacancies occurring and of duly qualified persons nominated by the Council for vacancies about to occur in the offices of President, Vice-Presidents, Hon. Treasurer, Hon. Secretary, and Ordinary Members of Council, is presented below for the information of the Members of the Society.

In the event of any Members desiring to put forward other names, the Council will be pleased to receive such nominations, which should be made in accordance with the following rule (Article 48):—

> "After the issue of the Council's list, and not later than the 15*th day of April* next following, any ten Members (but no more than ten) may nominate any other duly qualified person to fill any such vacancy by delivering such nominations in writing to the Hon. Secretary, together with the written consent of such person to accept office if elected, but each such nominator shall be debarred from nominating any other person for the same office at such election."

Nominated by the Council to fill Vacancies:—

President :—

Dr. H. BUCKLEY, F.INST.P., F.I.E.S.

Vice-Presidents :—

Dr. W. M. HAMPTON, PH.D., F.I.E.S.
Mr. H. C. WESTON, F.I.E.S.
Mr. E. STROUD, F.I.E.S.

Members of Council :—

Mr. H. E. CHASTENEY
Mr. W. E. J. DRAKE
Mr. F. S. ETTE
Mr. J. G. HOLMES
Mr. W. C. HUSTON
Mr. H. LINGARD
Mr. J. F. STANLEY
Dr. J. W. WHITAKER
Mr. T. WILKIE

Chairmen of Centres :— *(ex-officio)*

Mr. A. KELSO (Leeds)
(Manchester)
Mr. J. DICKSON (Glasgow)
Mr. A. J. PASHLER (Birmingham)
Mr. J. M. A. MITCHELL (Newcastle-on-Tyne)
Mr. A. HACKING (Nottingham)
(Sheffield)
Professor DAVID T. JONES (Cardiff)

Hon. Treasurer :—
Mr. N. V. EVERTON

Hon. Secretary :—
Mr. J. STEWART DOW

Sessional Meeting in London

A sessional meeting was held at Gas Industry House, 1, Grosvenor-place, London, S.W.1, at 5 p.m., on Tuesday, February 9, 1943, the President (Mr. R. O. Ackerley) presiding.

The minutes of the last meeting having been taken as read, the President explained that the meeting was to be devoted to a series of contributions on "The Effectiveness of Lighting: its Numerical Assessment." Short papers were then delivered by Dr. W. D. Wright (Subjective Brightness), Dr. K. J. W. Craik (Visual Acuity), Mrs. S. J. Macpherson (The Rate of Blinking), and Dr. W. S. Stiles (Thresholds).

A discussion then ensued, in which the following took part: Dr. J. W. T. Walsh, Mr. H. C. Weston, Mr. G. H. Giles, Mr. D. J. MacLean, Mr. R. Maxted, Mr. Imrie Smith, Mr. J. S. Dow, and Dr. N. H. Mackworth. The authors also joined in the discussion, commenting on each other's contributions.

The President, in winding up the discussion, emphasised the importance of studying the various aspects of lighting treated in these various contributions, and a cordial vote of thanks to the authors terminated the proceedings.

Additions to List of Members.

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members:—

SUSTAINING MEMBERS:—

City of Birmingham Electric Supply Dept...14, Dale End, BIRMINGHAM, 4.
Representative: R. H. Rawll.

Newey and Eyre, Ltd..18, Newhall Hill, BIRMINGHAM.
Representative: R. A. Corbett.

CORPORATE MEMBERS:—

Atherton, H. .....4, Durham Road, Pendleton, SALFORD, 6.
Best, A. .....77, College Road, Handsworth Wood, BIRMINGHAM, 20.
Bool, F. N. .....189, Green Lane, Rawmarsh, Near ROTHERHAM.
Burnett, P. V. .....2, High Street, Woking, SURREY.
Carr, H. .....18, Chandos Gardens, LEEDS, 8.
Coombs, A. Murray..Constitutional Club, Northumberland Avenue, LONDON, W.C.2.
Craig, W. G. .....38-39, Upper Thames Street, LONDON, E.C.4.
Ducker J. D. ..... "Fourways," 37, Atherton Road, Fulwood, PRESTON.
Elms, A. E. .....Lowlands, Greenway Road, Rumney, CARDIFF.
Henderson, D. C. ...78, Hazelhurst Brow, Daisy Hill, BRADFORD.
Hilton, J. W. .....Coronation Villa, Shenstone, Woodend, Near SUTTON COLDFIELD.
Mitchell, A. G. .....3, South Hill Park, Hampstead, LONDON, N.W.3.
Schofield, L. D. ....."Ambleside," 8, Cliff Road, Carlton, NOTTINGHAM.
Shaw, R. W. S. .....16, Oliver Avenue, CORSHAM.
Shield, A. .....Station Road, Shepley, Near HUDDERSFIELD.
Silvey, R. E. .....Slansor, Forge Lane, Bassaleg, MON.
Watson, J. .....3, Navenby Avenue, MANCHESTER, 16.
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